JC13 Rec'd PCT/PTO 21 MAR 2002

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 USC 371 AND 37 CFR 1.491**		ATTORNEY DOCKET NO. 401612 U.S. APPLICATION NO. 10/088674
INTERNATIONAL APPLICATION NO. PCT/JP00/06632	INTERNATIONAL FILING DATE September 27, 2000	PRIORITY DATE CLAIMED
TITLE OF INVENTION WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE		
APPLICANT(S) FOR DO/EO/US AKIYOSHI, ET AL.		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 USC 371 and 37 CFR 1.491.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 USC 371 and 37 CFR 1.491.
3. ☒ This is an express request to begin national examination procedures (35 USC 371(f)).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 USC 371(c)(2))
   - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☒ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 USC 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 USC 371(c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 USC 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 USC 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 USC 371(c)(5)).
11. Nucleotide and/or Amino Acid Sequence Submission
    - a. ☐ Computer Readable Form (CRF)
    - b. Specification Sequence Listing on:
      - i. ☐ CD-ROM or CD-R (2 copies); or
      - ii. ☐ Paper Copy
    - c. ☐ Statement verifying identity of above copies

Items 12 to 19 below concern other document(s) or information included:

12. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
    - ☐ Form PTO-1449
    - ☐ Copies of Listed Documents
13. ☒ An assignment for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
14. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☒ Application Data Sheet Under 37 CFR 1.76
18. ☒ Return Receipt Postcard
19. ☐ Other items or information:

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JC13 Rec'd PCT/PTO 21 MAR 2002

U.S. APPLICATION NO. 10/088674	INTERNATIONAL APPLICATION NO. PCT/JP00/06632	ATTORNEY DOCKET NO. 401612

				CALCULATIONS	PTO USE ONLY
20. ☐ The following fees are submitted: **Basic National Fee (37 CFR 1.492(a)(1)-(5)):** Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO........$1,040.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO........$890.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO, but international search fee (37 CFR 1.445(a)(2)) paid to USPTO........$740.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)........$710.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1) to (4)........$100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT=				$890.00	
Surcharge of $130.00 for furnishing the National fee or oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date				$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	6-20=		x $ 18.00	$	
Independent Claims	1- 3 =		x $ 84.00	$	
☐ Multiple Dependent Claim(s) (if applicable)			+$280.00	$	
TOTAL OF ABOVE CALCULATIONS=				$890.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$	
SUBTOTAL=				$890.00	
Processing fee of **$130.00** for furnishing English Translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date.				$	
TOTAL NATIONAL FEE=				$890.00	
Fee for recording the enclosed assignment. The assignment must be accompanied by an appropriate cover sheet. **$40.00** per property +				$40.00	
TOTAL FEE ENCLOSED=				$930.00	
				Amount to be: refunded	$
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a. ☒ A check in the amount of $930.00 to cover the above fee is enclosed.

b. ☐ Please charge Deposit Account No. 12-1216 in the amount of $ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 12-1216. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

23548
PATENT TRADEMARK OFFICE

Jeffrey A. Wyand, Reg. No. 29,458
LEYDIG, VOIT & MAYER, LTD.
700 Thirteenth Street, N.W., Suite 300
Washington, DC 20005-3960
(202) 737-6770 (telephone)
(202) 737-6776 (facsimile)

Date: March 21, 2002

PATENT
Attorney Docket No. 401612/ASAHINA

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

AKIYOSHI et al.

Application No. Unassigned

Filed: March 21, 2002

Art Unit: Unassigned

Examiner: Unassigned

For: WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Prior to the examination of the above-identified patent application, please enter the following amendments and consider the following remarks.

IN THE SPECIFICATION:

Replace the paragraph beginning at page 1, line 13 with:

In order to increase the machining speed, an example of a wire electrode for a wire electrical discharge machine, wherein core material (i.e., a core) is coated with a layer of Cu-Zn intermetallic compound, is disclosed in HITACHI CABLE REVIEW No. 18 (October 1999). A photograph of a cross section of this wire electrode is shown in Fig. 8. The figure is a magnification of a region near a surface of the wire electrode, wherein the coating layer of Cu-Zn intermetallic compound covering the core can be seen. In Fig. 8, the β phase of the intermetallic compound is seen in a string-like pattern and is surrounded by the α phase. Moreover, the outermost region of the wire electrode consists of only the α phase.

Replace the paragraph beginning at page 1, line 24 with:

The β phase, which has higher Zn concentration than the α phase, has an advantage of increasing machining speed, because the β phase easily evaporates through discharges to blow out object material. On the other hand, the β phase is brittle in a sense of metallography and has a disadvantage that there easily occur cracks during a cold wire drawing process in

manufacturing a wire electrode. Since the α phase with superior workability surrounds the β phase with difficult workability, a wire electrode as shown in Fig. 8 can be easily formed as a fine wire without any cracks or breaks during a cold wire drawing process.

Replace the paragraph beginning at page 2, line 6 with:

Further, a similar wire electrode for a wire electrical discharge machine is disclosed in Japanese Unexamined Patent Publication No. 300136/1997. Fig. 9 shows concentration of Zn in the radial direction of this wire electrode. The region near the surface of the wire electrode consists of the α phase and the Zn concentration is approximately 30 wt. %. In the case where Zn concentration exceeds 40 wt. %, there appears the β or γ phase having a different crystal structure from that of the α phase. At a depth of 5 to 30 μm from the surface of the wire electrode, the Zn concentration ranges from 35 to 45 wt. % where the α and β phases coexist and the Cu-Zn intermetallic compound with relatively high Zn concentration is formed.

Replace the paragraph beginning at page 3, line 3 with:

The present invention is made to solve the described problems and an object thereof is to increase Zn concentration in the coating layer and to improve the machining speed. A further object of the present invention is to remove object material efficiently and improve the machining speed and accuracy of machining, by improving the rigidity of the wire electrode and suppressing vibration during discharge machining.

Replace the paragraph beginning at page 4, line 4 with:

Fig. 4 is a graph showing a relationship between the thickness of a coating of Cu-Zn alloy in the α phase and machining speed;

Replace the paragraph beginning at page 4, line 7 with:

Fig. 5 is a graph showing a relationship between the thickness of a coating of Cu-Zn intermetallic compound in other than the α phase and machining speed;

Replace the paragraph beginning at page 4, line 10 with:

Fig. 6 is a graph showing machining speed of a wire electrode for a wire electrical discharge machine according to embodiment 2 of the present invention, compared with that of the conventional wire electrode;

Replace the paragraph beginning at page 4, line 14 with:

Fig. 7 is a graph showing machining speed of a wire electrode for a wire electrical discharge machine according to Embodiments 3 and 4 of the present invention, compared with that of the conventional wire electrode;

Replace the paragraph beginning at page 4, line 18 with:

Fig. 8 is a magnified photograph showing a cross section of the conventional wire electrode for a wire electrical discharge machine; and

Replace the paragraph beginning at page 4, line 20 with:

Fig. 9 is a graph showing Zn concentration in a radial direction of a cross section of a conventional wire electrode for a wire electrical discharge machine.

IN THE CLAIMS:

Replace the indicated claims with:

1. (Amended) A wire electrode for wire electrical discharge machining including a three-layer structure comprising an electrically conductive core, a first coating of Cu-Zn intermetallic compound in other than an α phase surrounding the core, and a second coating of Cu–Zn alloy in the α phase on the first coating, wherein the second coating has a thickness in a range from 5 to 15 μm.

2. (Amended) The wire electrode for wire electrical discharge machining according to Claim 1, wherein the first coating comprises Cu-Zn alloy in a β phase.

3. (Amended) The wire electrode for wire electrical discharge machining according to Claim 1, wherein the core comprises Cu-Zr alloy.

4. (Amended) The wire electrode for wire electrical discharge machining according to Claim 2, wherein the core comprises Cu-Zr alloy.

5. (Amended) The wire electrode for wire electrical discharge machining according to Claim 1, wherein the core comprises Cu-Zn alloy.

6. (Amended) The wire electrode for wire electrical discharge machining according to Claim 2, wherein the core comprises Cu-Zn alloy.

IN THE ABSTRACT:

Replace the Abstract with:

ABSTRACT

A wire electrode for electrical discharge machining has a three-layered structure of an electrically conductive core, a first coating of Cu-Zn intermetallic compound in other than an α phase, and a second coating of Cu-Zn alloy in the α phase on the first coating. The thickness of the second coating is 5 to 15 μm. The first coating layer is preferably Cu-Zn alloy in a β phase. The core is preferably Cu-Zr alloy.

REMARKS

The foregoing Amendment corrects translational errors and conforms the claims to United States practice. No new matter is added.

Respectfully submitted,

LEYDIG, VOIT & MAYER, LTD.

Jeffrey A. Wyand
Registration No. 29,458

Suite 300
700 Thirteenth Street, N.W.
Washington, D.C. 20005
Telephone: (202) 737-6770
Facsimile: (202) 737-6776
Date: March 21, 2002
JAW:ves

PATENT
Attorney Docket No. 401612/ASAHINA

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

AKIYOSHI et al.

Application No. Unassigned

Filed: March 21, 2002

For: WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE

Art Unit: Unassigned

Examiner: Unassigned

AMENDMENTS TO SPECIFICATION, CLAIMS AND ABSTRACT MADE VIA PRELIMINARY AMENDMENT

Amendments to the paragraph beginning at page 1, line 13:

In order to increase the machining speed, an example of a wire electrode for a wire electrical discharge machine, wherein core material (i.e., a core) is coated with a layer of Cu-Zn intermetallic compound, is disclosed in HITACHI CABLE REVIEW No. 18 (October 1999). A photograph of a cross section of this wire electrode is shown in Fig. 8. The figure is a magnification of a region near a surface of the wire electrode, wherein the coating layer of Cu-Zn intermetallic compound covering the core can be seen. In Fig. 8, the β phase of the intermetallic compound is seen in a string-like pattern and is surrounded by the α phase. Moreover, the outermost region of the wire electrode consists of only the α phase.

Amendments to the paragraph beginning at page 1, line 24:

The β phase, which has higher Zn concentration than the α phase, has an advantage ~~to increase~~ of increasing machining speed, because the β phase easily evaporates through discharges to blow out object material. On the other hand, the β phase is brittle in a sense of metallography and has a disadvantage that there easily occur cracks during a cold wire drawing process in manufacturing a wire electrode. Since the α phase with superior workability surrounds the β phase with difficult workability, a wire electrode as shown in Fig. 8 can be easily formed ~~to be~~ as a fine wire without any cracks or breaks during a cold wire drawing process.

Amendments to the paragraph beginning at page 2, line 6:

Further, a similar wire electrode for a wire electrical discharge machine is disclosed in Japanese Unexamined Patent Publication No. 300136/1997. Fig. 9 shows concentration of Zn in <u>the</u> radial direction of this wire electrode. ~~Region~~ <u>The region</u> near <u>the</u> surface of the wire electrode consists of <u>the</u> α phase and the Zn concentration is approximately 30 wt. %. In the case where Zn concentration exceeds 40 wt. %, there appears <u>the</u> β or γ phase having a different crystal structure from that of <u>the</u> α phase. At ~~the~~ <u>a</u> depth of 5 to 30 μm from the surface of the wire electrode, <u>the</u> Zn concentration ranges from 35 to 45 wt. % where <u>the</u> α and β phases coexist and <u>the</u> Cu-Zn intermetallic compound with relatively high Zn concentration is formed.

Amendments to the paragraph beginning at page 3, line 3:

The present invention is made to solve the ~~above~~ <u>described</u> problems and an object thereof is to increase Zn concentration in the coating layer and to improve the machining speed. A further object of the present invention is to remove object material efficiently and improve the machining speed and accuracy of machining, by improving the rigidity of <u>the</u> wire electrode and suppressing ~~the~~ vibration during <u>discharge</u> machining.

Amendments to the paragraph beginning at page 4, line 4:

Fig. 4 is a graph showing a relationship between the thickness of a coating ~~layer 3~~ of Cu-Zn alloy in <u>the</u> α phase and machining speed;

Amendments to the paragraph beginning at page 4, line 7:

Fig. 5 is a graph showing a relationship between the thickness of a coating ~~layer 2~~ of Cu-Zn intermetallic compound in other than <u>the</u> α phase and machining speed;

Amendments to the paragraph beginning at page 4, line 10:

Fig. 6 is a graph showing machining speed of a wire electrode for a wire electrical discharge machine according to embodiment 2 of the present invention, ~~comparing~~ <u>compared</u> with that of the conventional wire electrode;

Amendments to the paragraph beginning at page 4, line 14:

Fig. 7 is a graph showing machining speed of a wire electrode for a wire electrical discharge machine according to Embodiments 3 and 4 of the present invention~~, comparing~~ compared with that of the conventional wire electrode;

Amendments to the paragraph beginning at page 4, line 18:

Fig. 8 is a magnified photograph showing a cross section of the conventional wire electrode for a wire electrical discharge machine; and

Amendments to the paragraph beginning at page 4, line 20:

Fig. 9 is a graph showing Zn concentration in a radial direction of a cross section of a conventional wire electrode for a wire electrical discharge machine.

Amendments to existing claims:

1. (Amended) A wire electrode for wire electrical discharge~~ machine characterized in that the wire electrode has~~ machining including a~~ three-layered~~ three-layer structure comprising an~~ electroconductive~~ electrically conductive core~~ (1)~~, a first coating~~ layer (2)~~ of Cu-Zn~~ intermetalic~~ intermetallic compound in other than an α phase surrounding the core~~ (1)~~, and a second coating~~ layer (3)~~ of Cu–Zn alloy in the α phase on the~~ exterior of the~~ first coating~~ layer (2), and that the thickness of~~ wherein the second coating~~ layer (3) is~~ has a thickness in a range from 5 to 15 μm.

2. (Amended) The wire electrode for wire electrical discharge~~ machine~~ machining according to Claim 1~~, characterized in that~~ wherein the first coating~~ layer (2)~~ comprises Cu-Zn alloy in a β phase.

3. (Amended) The wire electrode for wire electrical discharge~~ machine~~ machining according to Claim 1~~, characterized in that~~ wherein the core~~ (1)~~ comprises Cu-Zr alloy.

4. (Amended) The wire electrode for wire electrical discharge~~ machine~~ machining according to Claim 2~~, characterized in that~~ wherein the core~~ (1)~~ comprises Cu-Zr alloy.

5. (Amended) The wire electrode for wire electrical discharge~~ machine~~ machining according to Claim 1~~, characterized in that~~ wherein the core~~ (1)~~ comprises Cu-Zn alloy.

6. (Amended) The wire electrode for wire electrical discharge ~~machine~~ machining according to Claim 2, ~~characterized in that~~ wherein the core ~~(1)~~ comprises Cu-Zn alloy.

Amendments to the abstract:

ABSTRACT

~~The present invention aims to increase concentration of Zn in a coating layer to enhance machining speed. Moreover, the present invention aims to perform removal of object material efficiently and enhance machining speed as well as accuracy in machining by increasing rigidity of the wire electrode to suppress vibration thereof during machining process.~~

~~The present invention is characterized in that the~~A wire electrode for ~~wire~~ electrical discharge ~~machine is constituted as~~ machining has a three-layered structure of an ~~electroconductive~~ electrically conductive core ~~(1)~~, a first coating ~~layer (2)~~ of Cu-Zn ~~intermetaric~~ intermetallic compound in other than an α phase, and a second coating ~~layer (3)~~ of Cu-Zn alloy in the α phase on ~~the exterior of~~ the first coating ~~layer (2), and that the~~. The thickness of the second coating ~~layer (3)~~ is ~~set to~~ 5 to 15 μm. ~~Furthermore, the~~ The first coating layer ~~(2)~~ is preferably Cu-Zn alloy in a β phase. ~~Moreover, the~~ The core ~~(1)~~ is preferably ~~made of~~ Cu-Zr alloy.

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PATENT
Attorney Docket No. 401612/ASAHINA

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

AKIYOSHI et al.

Application No. Unassigned

Filed: March 21, 2002

For: WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE

Art Unit: Unassigned

Examiner: Unassigned

PENDING CLAIMS AFTER ENTRY OF PRELIMINARY AMENDMENT

1. A wire electrode for wire electrical discharge machining including a three-layer structure comprising an electrically conductive core, a first coating of Cu-Zn intermetallic compound in other than an α phase surrounding the core, and a second coating of Cu–Zn alloy in the α phase on the first coating, wherein the second coating has a thickness in a range from 5 to 15 μm.

2. The wire electrode for wire electrical discharge machining according to Claim 1, wherein the first coating comprises Cu-Zn alloy in a β phase.

3. The wire electrode for wire electrical discharge machining according to Claim 1, wherein the core comprises Cu-Zr alloy.

4. The wire electrode for wire electrical discharge machining according to Claim 2, wherein the core comprises Cu-Zr alloy.

5. The wire electrode for wire electrical discharge machining according to Claim 1, wherein the core comprises Cu-Zn alloy.

6. The wire electrode for wire electrical discharge machining according to Claim 2, wherein the core comprises Cu-Zn alloy.

DESCRIPTION

WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE

TECHNICAL FIELD

The present invention relates to a wire electrode to be used in a discharge machining with a wire electrical discharge machine.

BACKGROUND ART

A wire electrical discharge machine is a device which machines a workpiece by discharges between a wire electrode and the workpiece.

In order to increase the machining speed, an example of a wire electrode for a wire electrical discharge machine, wherein core material (i.e. a core) is coated with a layer of Cu-Zn intermetallic compound, is disclosed in HITACHI CABLE REVIEW No.18 (October 1999). A photograph of cross section of this wire electrode is shown in Fig. 8. The figure is a magnification of region near surface of the wire electrode, wherein the coating layer of Cu-Zn intermetallic compound covering the core can be seen. In Fig. 8, β phase of the intermetallic compound is seen in a string-like pattern and is surrounded by α phase. Moreover, the outermost region of the wire electrode consists of only α phase.

β phase which has higher Zn concentration than α phase has an advantage to increase machining speed, because β phase easily evaporates through discharges to blow out object material. On the other hand, β phase is brittle in a sense of metallography and has a

disadvantage that there easily occur cracks during a cold wire drawing process in manufacturing a wire electrode. Since α phase with superior workability surrounds β phase with difficult workability, a wire electrode as shown in Fig. 8 can be easily formed to be a fine wire without any cracks or breaks during a cold wire drawing process.

Further, a similar wire electrode for a wire electrical discharge machine is disclosed in Japanese Unexamined Patent Publication No.300136/1997. Fig. 9 shows concentration of Zn in radial direction of this wire electrode. Region near surface of the wire electrode consists of α phase and the Zn concentration is approximately 30 wt. %. In the case where Zn concentration exceeds 40 wt. %, there appears β or γ phase having a different crystal structure from that of α phase. At the depth of 5 to 30 μm from the surface of the wire electrode, Zn concentration ranges from 35 to 45 wt. % where α and β phases coexist and Cu-Zn intermetallic compound with relatively high Zn concentration is formed.

As already described, although β and γ phases show the effect to blow out debris of the object material during electrical discharge machining and can enhance the machining speed, those are brittle in a sense of metallography and have a difficulty in cold wire drawing in wire electrode manufacturing.

Thus, in the conventional wire electrode for a wire electrical discharge machine, core material (i.e. a core) is surrounded by a layer of Cu-Zn intermetallic compound comprising β and α phases. Therefore, there are limitations in increasing Zn concentration of the Cu-Zn intermetallic layer and improving machining speed. Further, since β phase is surround by α phase, the effect of improvement in rigidity of the

wire electrode which β phase intrinsically has cannot be exhibited adequately.

The present invention is made to solve the above problems and an object thereof is to increase Zn concentration in the coating layer and to improve the machining speed. A further object of the present invention is to remove object material efficiently and improve the machining speed and accuracy of machining, by improving the rigidity of wire electrode and suppressing the vibration during machining.

DISCLOSURE OF INVENTION

The present invention is characterized in that a wire electrode has three-layered structure of an electroconductive core (1), a coating layer (2) made of Cu-Zn intermetallic compounds existing as other than α phase, and an outer coating layer (3) made of Cu-Zn alloy existing as α phase, and that thickness of the coating layer (3) is 5 to 15 μm.

Further, the coating layer (2) is preferably Cu-Zn alloy in β phase.

Moreover, the core (1) is preferably made of Cu-Zr alloy.

Furthermore, the core (1) might be made of Cu-Zn alloy.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a diagram showing a cross section of a wire electrode for a wire electrical discharge machine according to the present invention;

Fig. 2 is a photograph showing a cross section of a wire electrode for a wire electrical discharge machine according to the present invention;

Fig. 3 is a graph showing Zn concentration in a radial direction of cross section of a wire electrode for a wire electrical discharge machine according to the present invention;

Fig. 4 is a graph showing a relationship between the thickness of a coating layer 3 of Cu-Zn alloy in α phase and machining speed;

Fig. 5 is a graph showing a relationship between the thickness of a coating layer 2 of Cu-Zn intermetallic compound in other than α phase and machining speed;

Fig. 6 is a graph showing machining speed of a wire electrode for a wire electrical discharge machine according to embodiment 2 of the present invention, comparing with that of the conventional wire electrode;

Fig. 7 is a graph showing machining speed of a wire electrode for a wire electrical discharge machine according to Embodiments 3 and 4 of the present invention, comparing with that of the conventional wire electrode;

Fig. 8 is a magnified photograph showing cross section of the conventional wire electrode for a wire electrical discharge machine; and

Fig. 9 is a graph showing Zn concentration in a radial direction of cross section of a conventional wire electrode for a wire electrical discharge machine.

BEST MODE FOR CARRYING OUT THE INVENTION

EMBODIMENT 1

A wire electrode for a wire electrical discharge machine

according to an embodiment of the present invention is described with referring to Fig. 1. Fig. 1 shows a cross section of the wire electrode. The wire electrode according to the present invention has a three-layered structure wherein a coating layer 2 of Cu-Zn intermetallic compound in other than α phase surrounds an electroconductive core 1, and a coating layer 3 of Cu-Zn alloy in α phase is formed outside the coating layer 2. The Cu-Zn intermetallic compound which constitutes the coating layer 2 is in other than α phase and the thickness thereof is increased to the utmost. Since the workability of wire drawing in wire electrode manufacturing becomes worse by increasing the thickness of the phase other than α phase, the thickness of coating layer 3 which is in α phase is increased as much as possible.

Fig. 2 shows a photograph of cross section of the wire electrode of the present invention. There can be clearly seen that the coating layer 3 of Cu-Zn alloy in α phase and the coating layer 2 of Cu-Zn intermetallic compound in other than α phase is clearly separated from each other to form a three-layered structure including the core 1.

The coating layer 2 of Cu-Zn intermetallic compound in other than α phase has higher Zn concentration compared with the coating layer 3 of Cu-Zn alloy in α phase. In Fig. 3, Zn concentration in a radial direction of cross section is shown for the wire electrode of the present invention. In the region where the distance from the wire electrode surface is 0 to 15 μm, the coating layer 3 of Cu-Zn alloy in α phase exists and Zn concentration is around 35 wt. %. In the region where the distance from the wire electrode surface is 15 to 40 μm, the coating layer 2 of Cu-Zn intermetallic layer in other than α phase exists and Zn concentration is around 45 wt. %.

In a machining process with a wire electrical discharge machine, once a single discharge occurs between the workpiece and the wire electrode, the discharge point of the wire electrode is eroded by 5 to 10 μm in a radial direction. Therefore, even if the thickness of the coating layer 3 of Cu-Zn intermetallic compound in α phase is set to 5 to 15 μm according to the present invention, the coating layer 2 of Cu-Zn intermetallic compound in other than α phase and with a high Zn concentration is exposed to the surface by one to three discharge(s) happened at the same point. Cu-Zn inter metallic compound in other than α phase, especially β phase that firstly appears when increasing Zn concentration of α phase, has larger effects of evaporating and blowing off the object material through discharges than those of α phase. Thus, because of appearance of the coating layer 2 of Cu-Zn intermetallic compound in other than α phase at the surface, machining speed by discharges can be enhanced.

Fig. 4 shows a relationship between the thickness of the coating layer 3 of Cu-Zn alloy in α phase and machining speed. The thickness of the coating layer 2 of intermetallic compound in other than α phase is constant to be 25 μm. As is apparent from Fig. 4, machining speed is nearly constant when thickness of the coating layer 3 of Cu-Zn alloy in α phase is not more than 15 μm. That is, when thickness of the coating layer 3 of Cu-Zn alloy in α phase is not more than 15 μm, machining speed can be increased since the coating layer 2 of Cu-Zn intermetallic compound in other than α phase appears at the surface through one or two discharge(s).

When thickness of the coating layer 3 of Cu-Zn alloy in α phase is not more than 5 μm, wire drawing workability in manufacturing

wire electrodes becomes extremely worse. Therefore, thickness of the coating layer 3 of Cu-Zn alloy in α phase is preferably larger than 5 μm and within 15 μm.

Fig. 5 shows a relationship between the thickness of the coating layer 2 of Cu-Zn intermetallic compound in other than α phase and machining speed. The thickness of the coating layer 3 of Cu-Zn alloy in α phase is constant to be 15 μm. The larger the thickness of the coating layer 2 of Cu-Zn intermetallic compound in other than α phase having a high Zn concentration is, the more machining speed is improved.

For a wire electrode having a diameter of 0.3 mm, if the thickness of the coating layer 2 of Cu-Zn intermetallic layer in other than α phase is set to 20 to 40μm, the coating layer 2 is not exhausted during electric discharge machining process so that machining can be stable and the speed thereof can be remarkably increased.

It is because there occurs difficulty in workability during wire electrode manufacturing that whole cross section except the outermost coating layer 3 cannot be made of Cu-Zn intermetallic compounds in other than α phase.

Although diameter of the wire electrode is 0.3mm in the above example, similar effect can be obtained for the case in which diameter of the wire electrode is 0.1 to 0.4mm. The reason therefore is that diameter of the core 1 is required so as not to break, with bearing tension which is applied for retaining the wire electrode, hence, minimum diameter of the wire electrode including the coating layers 2 and 3 is required to be approximately 0.1mm. Further, maximum diameter is not limited, but considering the process of wire electrode

production and industrial application for the electric discharge machine, approximately 0.4mm is practical. Meanwhile, diameter of the core 1 is about 0.22mm in the case where diameter of the wire electrode is 0.3mm.

EMBODIMENT 2

In the present embodiment, a wire electrode has a three-layered structure wherein a core 1 having a diameter of 0.22mm is surrounded by a coating layer 2 of Cu-Zn alloy in β phase having a thickness of 30 μm and further the periphery of the coating layer 2 is coated with a coating layer 3 of Cu-Zn alloy in α phase having a thickness of 10μm.

In Fig. 6, machining speed of this wire electrode is shown in comparison with that of the conventional wire electrode. As a conventional wire electrode, there was used one wherein a core having a diameter of 0.22mm is surrounded by Cu-Zn intermetallic layer having a thickness of 20 μm and in which β phase is surrounded by α phase, and the periphery of the intermetallic layer is surrounded by Cu-Zn alloy in α phase having a thickness of not more than 5 μm. As core material, Cu-Zn alloy with 35 wt. % Zn concentration was used for both of the present embodiment and the conventional wire electrode.

In Fig. 6, discharge energy IP is shown in abscissa while machining speed is shown in ordinate, and a curved line S1 denotes the wire electrode in the present embodiment while a curved line P1 denotes the conventional wire electrode. For the wire electrode of the present embodiment, an increase in machining speed by 30 mm^2/min is seen at maximum compared with the conventional wire, which is found to be

very useful in industrial application.

EMBODIMENT 3

A wire electrode is exposed to extremely high temperature during wire electrical discharge machining. In the present embodiment, therefore, Cu-Zr alloy which shows little degradation in electrical conductivity and in mechanical strength to suppress vibration of the wire electrode even at a high temperature is used for a core 1, a coating layer 2 of Cu-Zn intermetallic compound in other than α phase is formed on the periphery of the core 1, and further a coating layer 3 of Cu-Zn alloy in α phase is formed on the periphery of the coating layer 2 to form a wire electrode having a three-layered structure.

In Fig. 7, machining speed of this wire electrode is shown in comparison with that of the conventional wire electrode. As the conventional wire electrode, there was used one wherein a core of Cu-Zn alloy having a diameter of 0.22mm is surrounded by Cu-Zn intermetallic layer having a thickness of 20 μm and in which β phase is surrounded by α phase, and the periphery of the intermetallic layer is surrounded by Cu-Zn alloy in α phase having a thickness of not more than 5 μm is used.

In Fig. 7, discharge energy IP is shown in abscissa while machining speed is shown in ordinate, and a curved line S2 denotes the wire electrode of the present embodiment while a curved line P2 denotes the conventional wire. The wire electrode of the present embodiment, in addition to an effect of blowing off the debris originated from discharges thanks to the coating layer 2 of Cu-Zn intermetallic compound in other than α phase, decreases an energy loss thanks to

improvement in electrical conductivity, resulting in increase of energy contributing for discharges and increase in machining speed by 30 mm^2/min at maximum compared with the conventional wire electrode, which is found to be very useful in industrial application.

Further, similar effect of increase in machining speed thanks to the coating layers 2 and 3 can be obtained when the core 1 of Cu-Zr alloy is substituted by inexpensive and easily available Cu-Zn alloy which has higher tensile strength so as to suppress vibration of the wire electrode.

EMBODIMENT 4

In the present embodiment, a wire electrode has a three-layered structure, wherein a coating layer 2 of Cu-Zn alloy in β phase is formed to surround a core 1 of Cu-Zr alloy and the periphery of the coating layer 2 is coated with a coating layer 3 of Cu-Zn alloy in α phase.

In Fig. 7, machining speed of the wire electrode according to the present embodiment is shown with a curved line S3. In addition to an effect of β phase Cu-Zn intermetaric compound layer 2 to blow off the debris generated through discharges, decrease in energy loss thanks to improvement in electrical conductivity results in increase of energy contributing for discharges so that machining speed is increased like in the case of Embodiment 3, thereby the wire electrode of the present embodiment is very useful in an industrial application.

Further, similar effect of increase in machining speed thanks to the coating layers 2 and 3 can be obtained when the core 1 of Cu-Zr alloy is substituted by inexpensive and easily available Cu-Zn alloy which has higher tensile strength so as to suppress vibration of the wire

electrode.

INDUSTRIAL APPLICABILITY

According to Embodiment 1 of the present invention, since the thickness of the coating layer 3 of Cu-Zn alloy in α phase is set to 5 to 15 μm, the wire electrode of fine diameter is easily formed without generation of any cracks and breaks even if the thickness of the coating layer 2 of Cu-Zn metallic compound in other than α phase is increased, and also high machining speed can be obtained thanks to the existence of the coating layer 2 of Cu-Zn metallic compound in other than α phase with high Zn concentration.

According to Embodiment 2 of the present invention, since the thickness of the coating layer 3 of Cu-Zn alloy in α phase is set to 5 to 15 μm, the wire electrode of fine diameter can be easily formed without generation of any cracks and breaks even if the thickness of the coating layer 2 of Cu-Zn alloy in β phase is increased. Further, high machining speed can be obtained thanks to the existence of the coating layer 2 of Cu-Zn alloy in β phase with high Zn concentration which has a large effect of blowing off the object material during discharges. Furthermore, since rigidity of the wire electrode is increased by the existence of β phase, vibration of the wire electrode during machining process is suppressed so that elimination of the object material is efficiently performed, and machining speed as well as accuracy in machining are enhanced.

According to Embodiment 3 of the present invention, since the thickness of the coating layer 3 of Cu-Zn alloy in α phase is set to 5 to 15 μm, the wire electrode of fine diameter is easily formed without

generation of any cracks and breaks even if the thickness of the coating layer 2 of Cu-Zn metallic compound in other than α phase is increased, and also high machining speed can be obtained thanks to the existence of the coating layer 2 of Cu-Zn metallic compound in other than α phase with high Zn concentration. Furthermore, by using Cu-Zr alloy for the core, electrical conductivity does not decrease even at a high temperature, which results in suppressing the discharge energy loss at the wire electrode and can increases the machining speed.

Meanwhile, by using Cu-Zn alloy with a high tensile strength for the core 1, vibration of the wire electrode is suppressed and higher machining speed can be achieved.

According to Embodiment 4 of the present invention, since the thickness of the coating layer 3 of Cu-Zn alloy in α phase is set to 5 to 15 μm, the wire electrode of fine diameter can be easily formed without generation of any cracks and breaks even if the thickness of the coating layer 2 of Cu-Zn alloy in β phase is increased. Furthermore, high machining speed can be obtained thanks to the existence of the coating layer 2 of Cu-Zn alloy in β phase with high Zn concentration which has a large effect of blowing off the object material during discharges. Further, since rigidity of the wire electrode is increased by the existence of β phase, vibration of the wire electrode during machining process is suppressed so that elimination of the object material is efficiently performed, and machining speed as well as accuracy in machining are enhanced. Furthermore, by using Cu-Zr alloy for the core, electrical conductivity does not decrease even at a high temperature, which results in suppressing the discharge energy loss at the wire electrode and can increases the machining speed.

Meanwhile, by using Cu-Zn alloy with a high tensile strength for the core 1, vibration of the wire electrode is suppressed and higher machining speed can be achieved.

CLAIMS

1. A wire electrode for wire electrical discharge machine characterized in that the wire electrode has a three-layered structure comprising an electroconductive core (1), a coating layer (2) of Cu-Zn intermetalic compound in other than α phase surrounding the core (1), and a coating layer (3) of Cu–Zn alloy in α phase on the exterior of the coating layer (2), and that the thickness of the coating layer (3) is 5 to 15 μm.

2. The wire electrode for wire electrical discharge machine according to Claim 1, characterized in that the coating layer (2) comprises Cu-Zn alloy in β phase.

3. The wire electrode for wire electrical discharge machine according to Claim 1, characterized in that the core (1) comprises Cu-Zr alloy.

4. The wire electrode for wire electrical discharge machine according to Claim 2, characterized in that the core (1) comprises Cu-Zr alloy.

5. The wire electrode for wire electrical discharge machine according to Claim 1, characterized in that the core (1) comprises Cu-Zn alloy.

6. The wire electrode for wire electrical discharge machine

according to Claim 2, characterized in that the core (1) comprises Cu-Zn alloy.

ABSTRACT

The present invention aims to increase concentration of Zn in a coating layer to enhance machining speed. Moreover, the present invention aims to perform removal of object material efficiently and enhance machining speed as well as accuracy in machining by increasing rigidity of the wire electrode to suppress vibration thereof during machining process.

The present invention is characterized in that the wire electrode for wire electrical discharge machine is constituted as a three-layered structure of an electroconductive core (1), a coating layer (2) of Cu-Zn intermetaric compound in other than α phase and a coating layer (3) of Cu-Zn alloy in α phase on the exterior of the coating layer (2), and that the thickness of the coating layer (3) is set to 5 to 15 μm. Furthermore, the coating layer (2) is preferably Cu-Zn alloy in β phase. Moreover, the core (1) is preferably made of Cu-Zr alloy.

Title: WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE 10/088674
Inventors: AKIYOSHI, ET AL.
Atty Docket No.: 401612
Leydig, Voit & Mayer, Ltd. 202-737-6770

FIG. 1

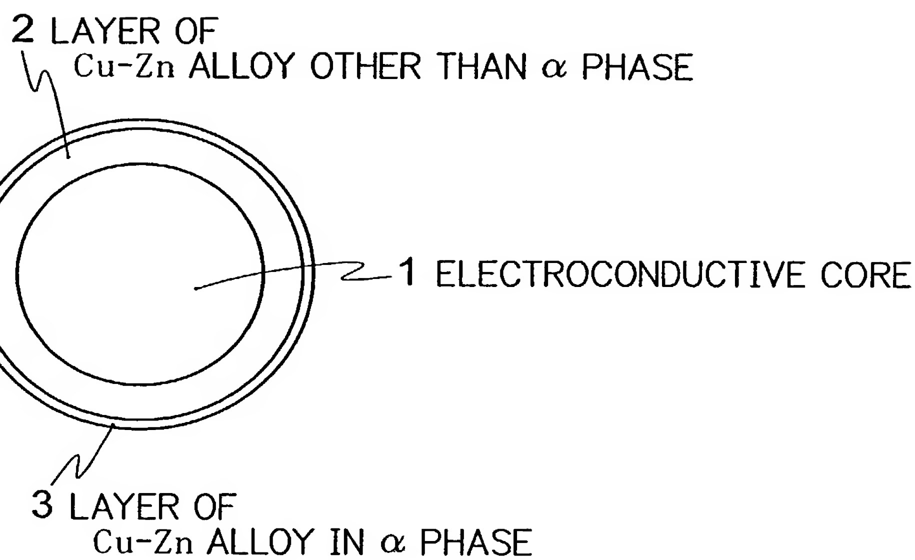


FIG. 2

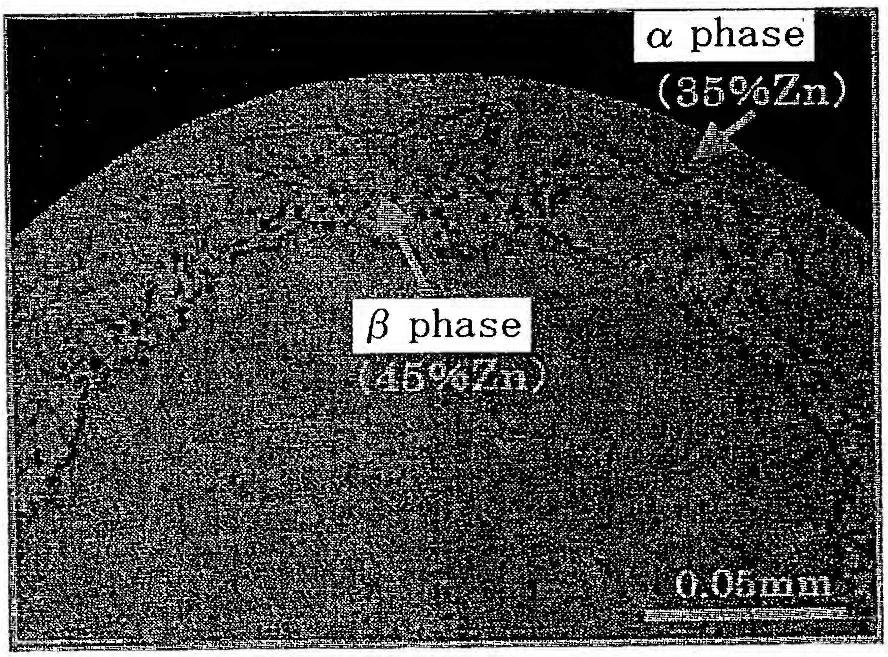


FIG. 3

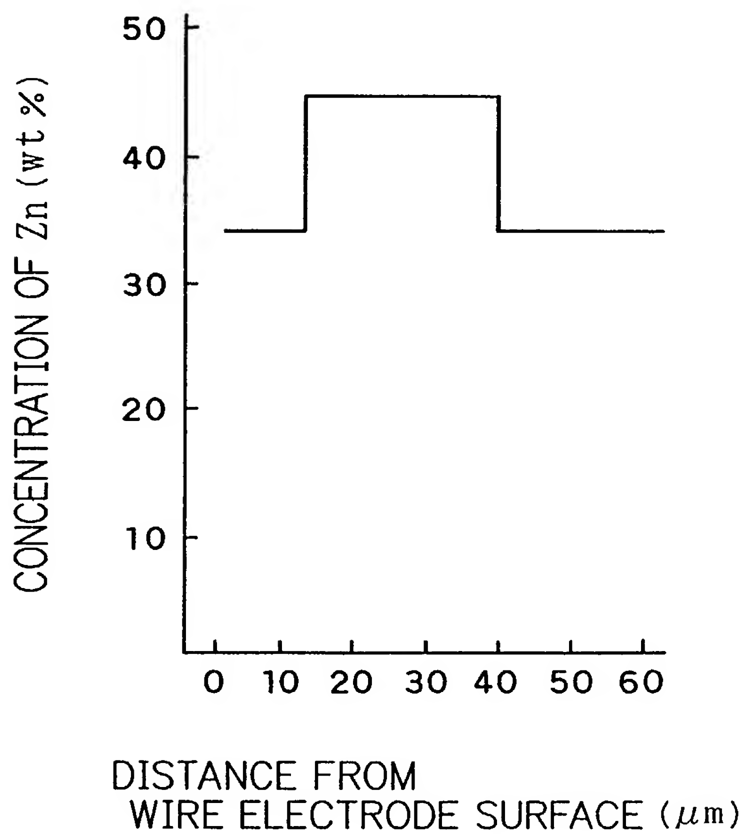

CONCENTRATION OF Zn (wt %)
50
40
30
20
10
0 10 20 30 40 50 60
DISTANCE FROM
WIRE ELECTRODE SURFACE (μm)

FIG. 4

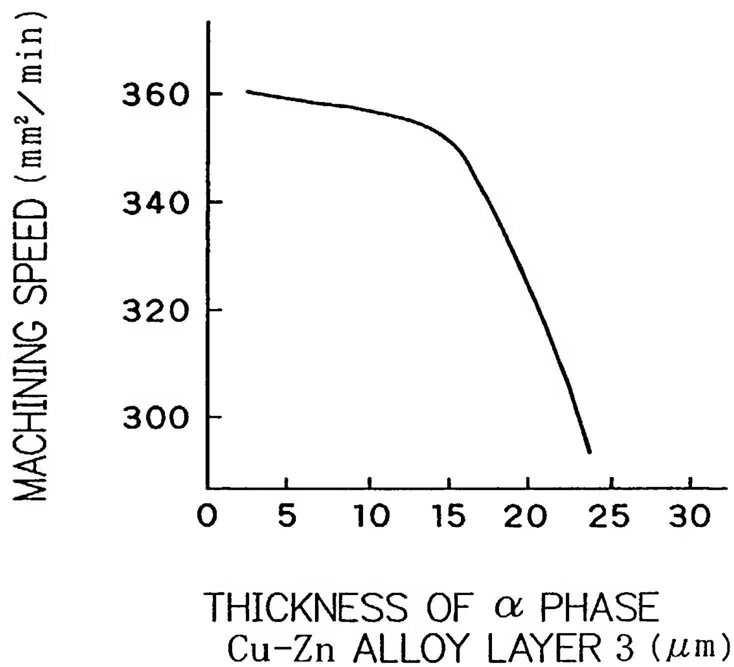

MACHINING SPEED (mm²/min)
360
340
320
300
0
5
10
15
20
25
30
THICKNESS OF α PHASE
Cu-Zn ALLOY LAYER 3 (μm)

FIG. 5

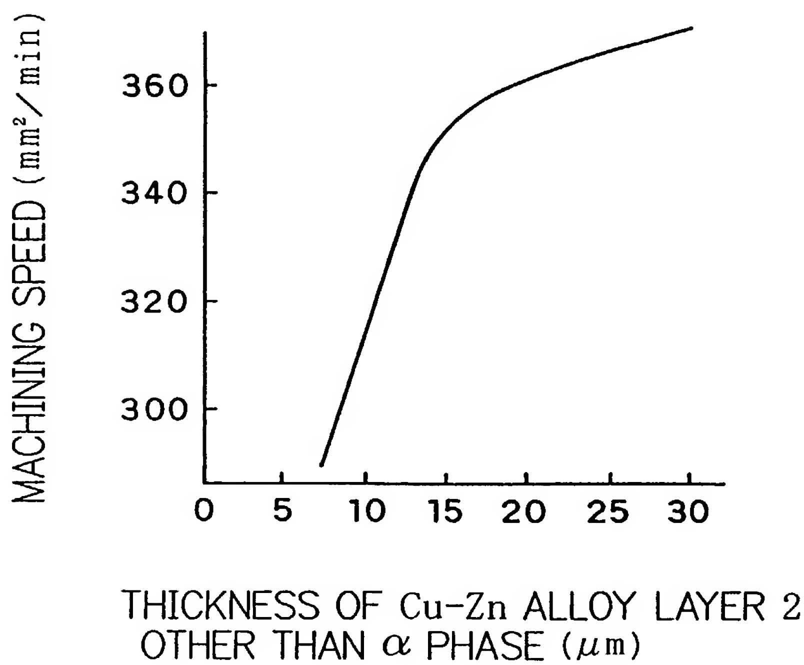
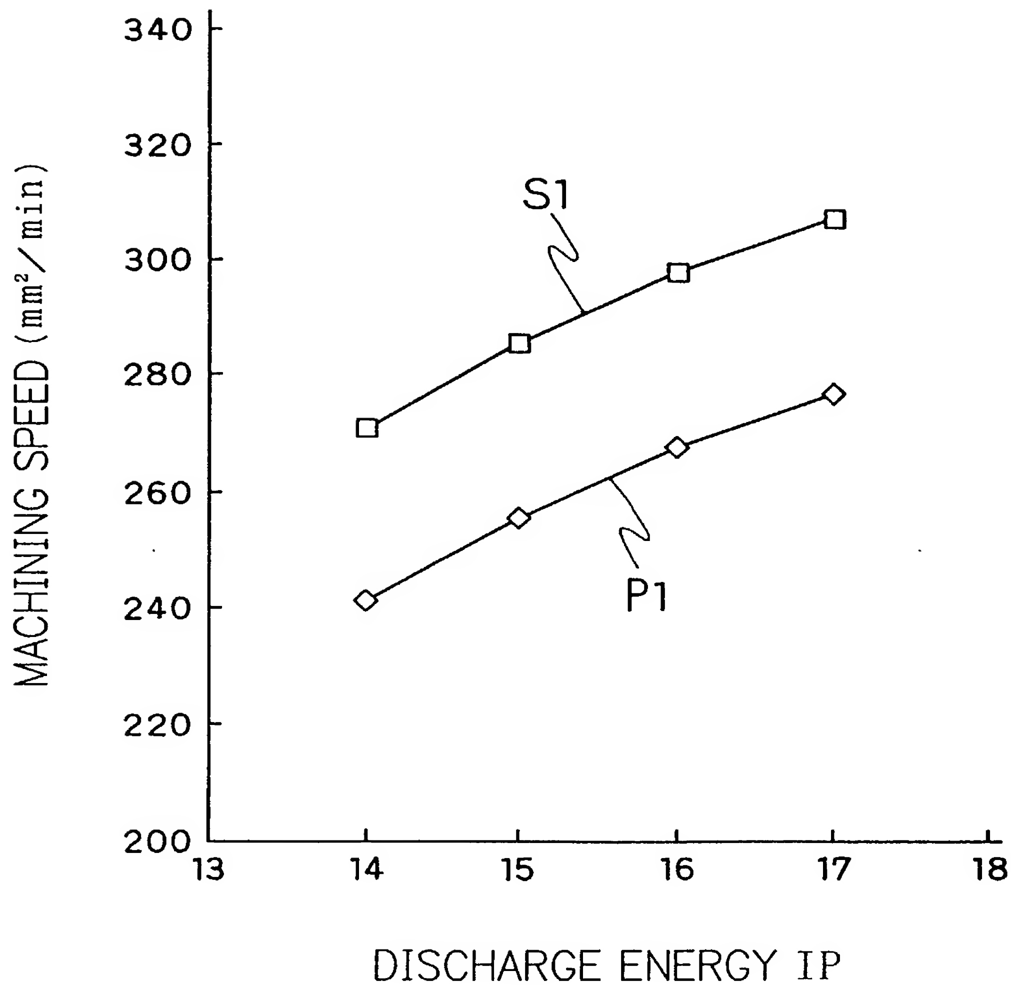

MACHINING SPEED (mm²/min)
360
340
320
300
0
5
10
15
20
25
30
THICKNESS OF Cu-Zn ALLOY LAYER 2
OTHER THAN α PHASE (μm)

FIG. 6


340
320
300
280
260
240
220
200
13
14
15
16
17
18
MACHINING SPEED (mm²/min)
S1
P1
DISCHARGE ENERGY IP

Title: WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE
Inventors: AKIYOSHI, ET AL.
Atty Docket No.: 401612
Leydig, Voit & Mayer, Ltd. 202-737-6770

FIG. 7

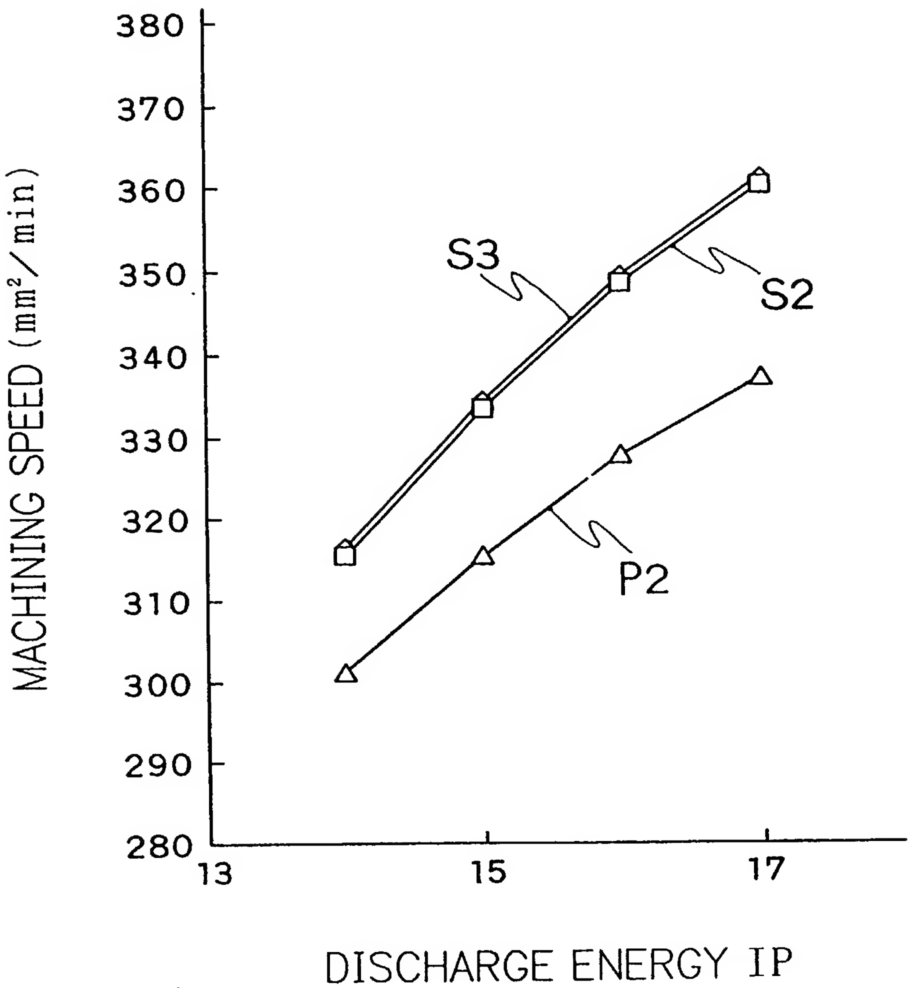
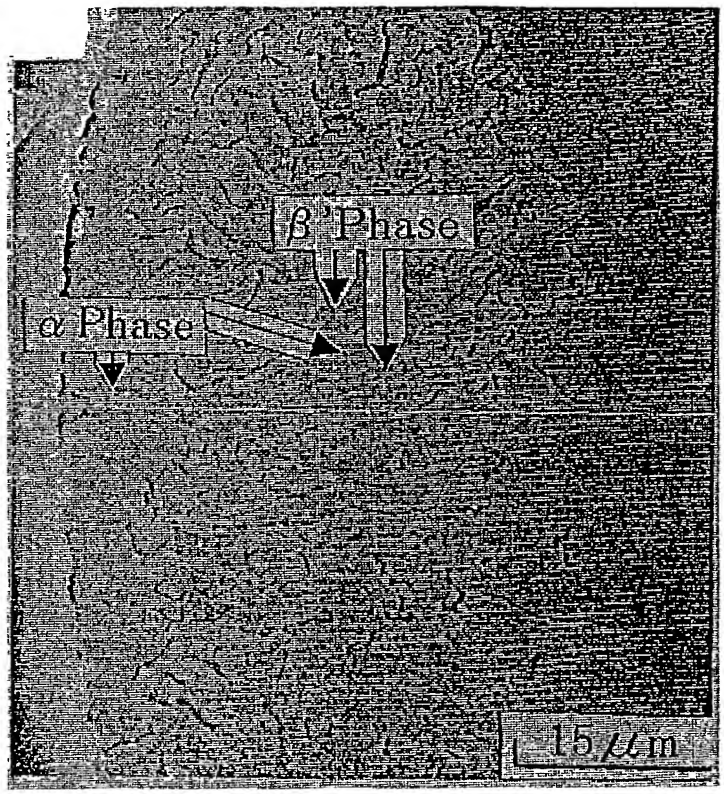


FIG. 8



Title: WIRE ELECTRODE FOR WIRE ELECTRICAL DISCHARGE MACHINE 10/088674
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Atty Docket No.: 401612
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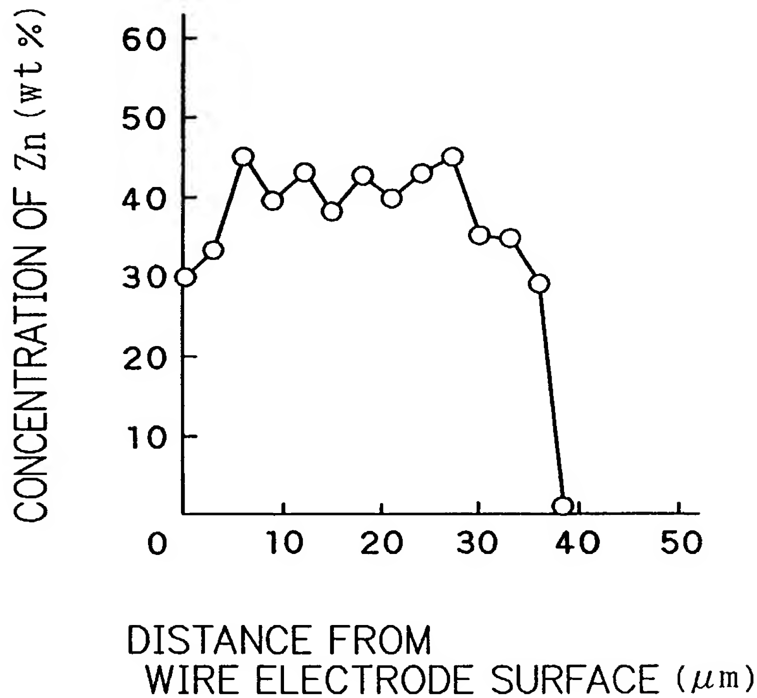
FIG. 9



Declaration and Power of Attorney for Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

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My residence, post office address and citizenship are as stated next to my name

下記の名称の発明について、特許請求範囲に記載され、且つ特許が求められている発明主題に関して、私は、最初、最先且つ唯一の発明者である（唯一の氏名が記載されている場合）か、或いは最初、最先且つ共同発明者である（複数の氏名が記載されている場合）と信じている。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

WIRE ELECTRODE FOR WIRE ELECTRICAL

DISCHARGE MACHINE

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＿＿＿＿＿＿ であり、且つ
＿＿＿＿＿＿ の日に補正された出願（該当する場合）

☒ was filed on September 27, 2000
as United States Application Number or
PCT International Application Number
PCT/JP00/06632 and was amended on
＿＿＿＿＿＿ (if applicable).

私は、上記の補正書によって補正された、特許請求範囲を含む上記明細書を検討し、且つ内容を理解していることをここに表明する。

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私は、ここに、以下に記載した外国での特許出願または発明者証の出願、或いは米国以外の少なくとも一国を指定している米国法典第３５編第３６５条(a)によるＰＣＴ国際出願について、同第１１９条(a)-(d)項又は第３６５条(b)項に基づいて優先権を主張するとともに、優先権を主張する本出願の出願日よりも前の出願日を有する外国での特許出願または発明者証の出願、或いはＰＣＴ国際出願については、いかなる出願も、下記の枠内をチェックすることにより示した。

I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application for which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

Priority Not Claimed
優先権主張なし

(Number)（番号）	(Country)（国名）	(Day/Month/Year Filed)（出願日／月／年）	☐
(Number)（番号）	(Country)（国名）	(Day/Month/Year Filed)（出願日／月／年）	☐

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(Application No.)（出願番号）	(Filing Date)（出願日）	(Application No.)（出願番号）	(Filling Date)（出願日）

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(Application No.)（出願番号）	(Filing Date)（出願日）	(Status: Patented, Pending, Abandoned)（現況：特許許可、係属中、放棄）
(Application No.)（出願番号）	(Filing Date)（出願日）	(Status: Patented, Pending, Abandoned)（現況：特許許可、係属中、放棄）

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10083674 .032102

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直通電話連絡先：（氏名及び電話番号）	Direct Telephone Calls to: (name and telephone number)
23548 PATENT TRADEMARK OFFICE	

唯一または第一発明者氏名	1-00	Full name of sole or first inventor Masao AKIYOSHI
発明者の署名	日付	Inventor's signature / Date Masao Akiyoshi 21/2/2002
住所		Residence Chiyoda-ku, Tokyo 100-8310 Japan JPX
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o MITSUBISHI DENKI KABUSHIKI KAISHA, 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8310 Japan
第二共同発明者がいる場合、その氏名	2-00	Full name of second joint inventor, if any Seiji SATOU 21/2/2002
第二共同発明者の署名	日付	Second inventor's signature / Date Seiji Satou
住所		Residence Chiyoda-ku, Tokyo 100-8310 Japan JPX
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o MITSUBISHI DENKI KABUSHIKI KAISHA, 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8310 Japan

（第三以下の共同発明者についても同様に記載し、署名をすること）

(Supply similar information and signature for third and subsequent joint inventors.)

第３の共同発明者の氏名（該当する場合） 3-00	Full name of third joint inventor, if any Seigi AOYAMA
同第３発明者の署名 日付	Third Inventor's signature Date Seigi Aoyama 18/2/2002
住所	Residence Kitaibaraki-shi, Ibaraki 319-1537 Japan JPX
国籍	Citizenship Japanese
郵便の宛先	Post Office Address 144, Shimosoda, Hanakawa-cho,
	Kitaibaraki-shi, Ibaraki 319-1537 Japan

第４の共同発明者の氏名（該当する場合） 4-00	Full name of forth joint inventor, if any Hiromitsu KURODA
同第４発明者の署名 日付	Forth Inventor's signature Date Hiromitsu Kuroda 18/2/2002
住所	Residence Hitachi-shi, Ibaraki 319-1416 Japan JPX
国籍	Citizenship Japanese
郵便の宛先	Post Office Address 2-27-31, Tajiri-cho, Hitachi-shi,
	Ibaraki 319-1416 Japan

第５の共同発明者の氏名（該当する場合） 5-00	Full name of fifth joint inventor, if any Takamitsu KIMURA
同第５発明者の署名 日付	Fifth Inventor's signature Date Takamitsu Kimura 18/2/2002
住所	Residence Hitachi-shi, Ibaraki 319-1416 Japan JPX
国籍	Citizenship Japanese
郵便の宛先	Post Office Address 7-36-27-203, Kawajiri-cho, Hitachi-shi,
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